# MEKELLE UNIVERSITY

CoDANR

College of Dryland Agriculture and Natural Resources

Department of dryland crop and horticultural science

# Evaluation of Potato (*Solanum tubersum* L.) Varieties for Growth and Yield under Different Planting Dates in the Lowlands of Raya Azaebo, Tigray, Northern Ethiopia.

By

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A Thesis Submitted in Partial Fulfilment of the Requirements for the Master of Science Degree In Horticulture

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# DECLARATION

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# AUTHOR’S BIOGRAPHY

The author, **Haftamu Hafte**, was born on November 12, 1989 E.C. at Mekhoni town, wereda Raya Azebo south Tigray Regional State. He attended his elementary school in 1997 E.C. at primary school of Warigba and the secondary schools in Mekhoni and preparatory school at Fenikl (Hayelom Areaya) school in Mekhoni. Following the completion of his preparatory education, he joined Mekelle University College of Dryland Agriculture and natural resource in 2009 and graduated with BSc Degree in crop science in July, 2011. After graduation, he immediately joined to the graduate studies program of Mekelle University College of dry land and Agriculture resources to a Master of Science degree in Horticulture.

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| FAO | World Food and Agricultural Organization |
| FAOSTAT | Food and Agricultural Organization of the United Nation Statistics |
| CSA | Central Statistical Agency |
| MASL | meter above sea level |
| EARO | Ethiopian Agricultural Research Organization |
| RCBD | randomized complete block design |
| ha | hectare |
| cm | cent meter |
| mm | mill meter |
| Qt | Quintals |

# DEDICATION

I dedicate this thesis to my family for nursing me with affections and love and their dedicated partnership for success in my life.

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# ABSTRACT

*Potato plays a crucial role in food security, poverty alleviation, and income generation in Tigray, particularly in the lowland areas of Raya-Azebo. However, its productivity remains low mainly due to the lack of suitable varieties and inappropriate planting dates. This study aimed to identify the optimal planting date and variety for improving potato yield and yield components in the lowland areas of Raya Azebo, Tigray. The experiment was conducted using three planting dates - October 17, November 2, and November 17- and three potato varieties (Belete, Gudane, and Jaleni), arranged in a Randomized Complete Block Design with three replications . Data on phenological, yield and yield related parameters were collected and analyzed using GenStat version 18. The results showed that planting date had a significant effect (P<0.001) on days to emergence, flowering, maturity, number of tubers per plant, average tuber weight, tuber diameter, total tuber yield, marketable and unmarketable tuber yields. Variety also significantly affected numbers of tubers per plant, average tuber weight, marketable yield and total tuber yield. Moreover, the interaction between planting date and variety significantly influenced days to emergence, number of tubers per plant, average tuber weight, tuber diameter, total tuber yield, and marketable tuber yield. Potato varieties planted on October 17$^{th}$ matured early. The Belete variety, planted on 2$^{nd}$ November, produced the highest marketable tuber yield (290.4 q ha$^{-1}$) while the Jalenne variety, planted on November 17, had the lowest yield (156 q ha$^{-1}$). Marketable tuber yield was negatively correlated with phenological traits, but showed a strong positive association with growth parameters, and yield components. Generally, planting potatoes during the first three weeks of October resulted in the highest marketable and total tuber yields, with November 2$^{nd}$ being the optimal planting date. It is recommended that smallholder farmers and the private sector adopt this planting date for improved potato production in lowland areas of Raya Azebo.*

**Key words-** growth parameters, planting date, Potato, varieties, tuber yield

# CHAPTER: ONE INTRODUCTION

## 1.1 Background

Potato (*Solanum tuberosum L.*) is a member of the *Solanaceae* family, and a diverse vegetable crop cultivated in various diverse agro-ecological zones (Burke 2017; CIP, 2017). It is grown from southern Chile to Greenland, at elevations of 4,700 meters above sea level (CIP, 2017). Potatoes are cultivated in several countries worldwide, including the highlands of the Democratic Republic of Congo, Burundi, and Rwanda, as well as the highland plateaus of West Africa in Cameroon and Nigeria. More than seven million smallholder potato farming households are found in the fertile, hilly regions of East, Central, West, and Southern Africa, extending from Ethiopia in the north to Mozambique on the southern coast (Abdulwahab et al., 2016). In addition to its wide geographical distribution, potato cultivation plays a crucial role in food production, employment, and income generation.

Potato is a key vegetable crop and ranks as the fourth most important food crop globally (Zaheer and Akhtar, 2016). It is rich in easily digestible carbohydrates, essential vitamins, and proteins, particularly lysine (Pęksa et al., 2013; Waglay and Karboune, 2016). Moreover, potatoes play a crucial role in combatting world hunger and malnutrition (Haverkort and Struik, 2015; Thiele et al., 2010). It produce a higher yield of edible food and offer superior nutrient density than cereals (Birch et al., 2012). Potatoes adaptability to various cropping systems and the diversity in nutrient levels among varieties enhance their value across human consumption, animal feed and industrial uses (Wijesinha-Bettoni, and Mouillé, 2019). Potatoes provides the highest  yield and energy per unite area, producing 58% and 74.5% more than other  staple cereal crops, respectively (Ahmed et al., 2017). However, it has been estimated that about 18 to 32% of potato yield is lost, and quality deteriorates due to improper planting dates and variety selection for specific agro-ecologies (Hijmans, 2003;  Tesfaye et al., 2013).

Potato was introduced to Ethiopia by German botanist Schimper in 1858 (Pankhurst, 1966), and today, over one million smallholder farmers cultivate potatoes (Milkias and Keba, 2021). According to a survey by the Ethiopian Central Statistics Agency, approximately 67,361.87 hectares of land are dedicated to potato farming (CSA, 2017). Major challenges include the lack of improved varieties, which are crucial for enhancing productivity (Schulte-Geldermann et al., 2014) with average tuber yield of 6 to 8 t $ha^{-1}$ (CSA, 2017). However, potato market prices have been raising, highlighting the need for further intensive research to address production challenges and improve productivity (Haile et al., 2015).

In Tigray, there are suitable seasons and agro-ecologies for the production of diverse potato varieties that are tolerant to biotic and abiotic stresses. Most potato farming zones fall within the main rainy season (*Kremti*), autumn (*Kewie*), and the short rainy season (*Belgi*) (Gildemacheret al., 2009). However, potato growers in most lowland areas of Mekhoni have not benefited from the *belgi* season’s reliable rainfall, mainly due to highly variable weather conditions, even within a single month (Geremedin et al., 2008).

As a result, determining appropriate potato planting dates for each district has become a critical factor influencing production. Proper planting time affects all environmental factors during growth, maturity, and yield potential (Ahmed et al., 2017). Studies indicated that adopting improved varieties and proper planting dates can significantly increase potato yield (Niguse et al., 2016). Despite the indispensable roles of planting dates and variety selection, no research has been conducted to determine the appropriate planting time for locally adapted potato varieties in Raya-Azebo. Therefore, selecting suitable varieties and scheduling planting dates properly are essential, as timely planting aligns crop growth stages with optimal environmental conditions, maximizing yield potential.

## 1.2. Statement of the problem and justification

Potato is widely produced using small scale irrigation facilities in the low land area of Raya Azebo, Tigray region. However, productivity remains significantly low (8.1t/ha), far below the national (13.77 t/ha), African (18.5 t/ha), and global (20 t/ha) averages (CSA, 2021). Several factors contribute to this low yield, including moisture stress, lack of improved varieties, limited access to quality seeds, and improper planting dates. Additionally, many farmers believe that potato cultivation is only suitable for highland agro-ecologies, despite its potential for successful production in lowlands. Many farmers mistakenly believe that potato production is only suitable for highland agro-ecologies, despite its potential for successful cultivation in lowland areas. Local farmers plant potatoes based on agronomic practices recommended for other Woredas and regions of the country without considering the local agroecology. Besides, farmers plant potato at any time without reconsidering and matching the suitable planting dates for several potato varieties. As a result, the average potato yield is very low (8.1 t $ha^{-1}$) which is far below the national average (13.77 t $ha^{-1}$), Africa (18.5 t $ha^{-1}$), and world (20 t $ha^{-1}$) average yields (CSA, 2021; Gebru et al., 2019).Therefore, Adopting improved potato varieties alongside best management practices, such as optimizing planting dates, could increase yields to 19–30 t/ha in dryland agro-ecologies similar to Raya Azebo. (Bymolt, 2014, Low et al., 2020).

Thus, this study aims to evaluate the performance of different potato varieties under various planting dates to determine the most suitable combination for the lowland areas of Raya Azebo. The findings will provide evidence-based recommendations for smallholder farmers, policymakers, and agricultural extension services to enhance potato production in the region.

## 1.3. Objective

### 1.3.1 General objective

- ✓ To evaluate the growth and yield performance of different potato varieties under various planting dates in the lowland areas of Raya Azebo.

### 1.3.2. Specific objectives

- ✓ To determine the optimal planting date for maximizing potato yield and yield components in the lowland areas of Raya Azebo.
- ✓ To identify the best-performing potato variety that produces the highest yield in the Raya Azebo district.

## 1.4. Significant of the study

Wereda Raya Azebo is one of the potential areas to produce cereal and horticultural crops as it has suitable soil and climatic conditions. Potato is also producing under irrigated condition but its yield is very low compared to other areas. So, to increase the production and productivity of potato in the study area, introduction of best potato varieties and planting in their appropriate date is important. Evaluating the growth and yield performance of potato under different planting date could help to identify suitable planting date and adaptable variety in the area to ensure food security and improve productivity. Hence, this study could have a profound importance for researchers, NGOs, government organizations, farmers, investors and other stakeholders, who participate in potato production.

# CHAPTER TWO: LITERATURE REVIEW

## 2.1. Origin and distribution of potato

Potato (*Solanum tuberosum L.*) is native to South America, most likely from Peru's central (Andes Machida-hirano and Niino, 2017), Indigenous farming communities have been cultivating it for more than 4,000 years after it was domesticated. The crop spread throughout the world after the Spanish brought it to Europe in the sixteenth century (Sukhotu and Hosaka, 2006). Wilhelm Schimper, a German immigrant, brought potatoes to Ethiopia in 1858. Ethiopian farmers adopted them gradually over the course of several decades (Kidane-Mariam 1980).

Today, potato is grown in 158 countries in tropical, subtropical, and temperate regions of the world (FAO, 2010; FAOSTAT, 2014). The potato was first domesticated in the region surrounding Lake Titicaca, which is 3800 meters above sea level on the border of present-day Bolivia and Peru in the Andes mountain range of South America (Hielke et al., 2011). Schimper, a German botanist, brought it to Ethiopia in 1858 (Tekalign, 2005 and FAO, 2014). The Solanaceae family includes the cultivated potato as well as other crops like peppers and tomatoes. When grown for botanical seed, it is an annual dicotyledonous, but because it is commercially propagated vegetativly from tubers, it is considered as a perennial (Mosley et al., 200). Its aboveground stem features alternating leaves with a pinnately compound pattern, and its underground storage stems or tubers are specialized (Decoteou, 2005). Potatoes are C3 plants with a low light saturation point and a moderate tolerance to frost (Hausler et al., 2001). Sprout development, vegetative growth, tuberization (tuber formation), tuber bulking, and tuber maturation are the five different stages of potato growth. It develops a fibrous adventitious root system and has an unpredictable growth pattern. On the underground part of the stem, this grows directly above the nodes (Dwelle and Love, 1993). In addition to serving as the primary means of potato propagation, the tuber is a significant source of food for humans. In contrast to sexual propagation, vegetative reproduction guarantees a consistent crop. Planting potato true seeds allows for sexual propagation, but due to the high degree of variability in these seeds, it is not frequently used. Nonetheless, sexual seeds is gaining popularity, particularly in areas where disease pressure is high and seed maintenance is becoming challenging (Mosley et al., 2000).

In reality, potato tubers are modified stems that contain roughly 70–75% water and the remaining 25–30% dry matter. Their eyes or node are where growth starts (Gericke, 2018). Sprouts are the new stems that emerge from each eye. After a period of dormancy following harvest, which varies significantly amongst cultivars, sprouts emerge from the tuber. Following the breaking of this dormancy, sprouts develop and, when planted, produce the plant stems and all of the plant's vegetative parts. The new tubers will develop from lateral shoots known as stolons that form underground (Mosley et al., 2000). The potato plant's main stem ends in a cluster of flowers. Even though flower bud abortion can happen very early in development, the main stem's apical growth stops when the flower forms.

## 2.2. Botanical description of potato

Potato is fibrous, comparatively shallow roots within 30 cm of the surface. Early in the growing season, the root system grows quickly, reaching its peak development by the middle of the season. Then, as the plant ages, its root mass, density, and length all decline. Under ideal soil conditions, potatoes have been known to reach root depths of 1.2 m or more (Tanner et al., 1982). From one season to the next, potatoes can survive in the field by vegetative means (as tubers). The potato is a specialized underground stem rather than a storage root, despite what many people think. The buds will emerge and grow into a plant above ground if a whole tuber or a portion of tuber with one or more eyes is planted. The root system is made up of adventitious roots that are grown by the developing sprout long before the plant emerges. Additionally, rhizomes, or stolon’s, grow from the stem's underground portion and may bear new tubers at their tips (Ewing, 1997). Although these stems can occasionally grow aboveground as well, in which case they are referred to as stolons, the potato tuber is an enlarged portion of an underground stem.The potato tuber has all the traits of a typical stem, such as lenticels (surface pores), rudimentary leaves (eyebrow scars lining the eyes), and dormant buds (eyes). Tuber's has spiral shaped buds, which are typically concentrated on the seed or apical end (the opposite end of the stem attachment) (Thomas et al., 2006). The potato plant's main stem ends in clusters of flowers. The clusters have yellow stamens and white, pink, red, blue, or purple flowers. Even though flower bud abortion can happen very early in development, the main stem's apical growth stops when the flower buds form (Tiwari, 2022).

Because sympodial growth of one or more auxiliary branches just below the apex permits further extension above the flower cluster, the main shoot axis may not clearly stop growing (Alemkinders and Struik, 1994). Although branching can happen at any node, it usually happens at the plant's base. On the main stem, some branches emerge from subterranean nodes. It is challenging to differentiate these from stems that have emerged from distinct eyes of the seed tuber without disturbing the soil. Nodes slightly above the soil's surface give rise to additional axillary branches. When assessing yield potential, the degree of axillary branching both sympodial and basal is vital. Offspring produced by tuber propagation are genetically identical.

This means that all tubers of a given cultivar should be uniform, unless they become infected with a disease cause organism (Ewing, 1997). Although potatoes are cultivated worldwide and belong to a single botanical species, their tubers exist in more than 5,000 varieties, differing significantly in size, shape, color, texture, cooking characteristics, and taste (FAO, 2010; CIP, 2014).

## 2.3. Importance of Potato

The potato is one of the most valuable crops in the world. In terms of production volume, it ranks fourth globally after rice, wheat, and maize (Razdan & Mattoo, 2005; FAO, 2010).According to the number of producing nations, it is the most popular root and tuber crop, followed by yams, sweet potatoes, and cassava (FA0, 2008). After sugarcane and sugar beet, it is the third-highest crop in terms of fresh matter yield (Khan et al., 2010).

Because it produces more dry-matter food, has proportionate protein, and produces more calories per unit area of land and time than other major food crops, it is an important crop that can significantly supplement the nation's food needs (Pandey, 2007). Because of its high carbohydrate content and substantial vitamin B, vitamin C, and mineral content, it is an inexpensive energy source. Compared to other staple crops, potatoes offer more calories, vitamins, and nutrients per acre of land planted (Schott et al., 2000).

A medium-sized potato tuber (150 grams), including the skin, contains 29.55 milligrams of vitamin C, which is 45% of the daily value (U.S. Department of Agriculture, 2007). This is significant because vitamin C, a vital scurvy deterrent, is absent from other staple crops like wheat, oats, barley, rice, and maize (Rao and Annadana 2017. In addition, a medium potato has substantial levels of thiamin, riboflavin, folate, niacin, magnesium, phosphorus, iron, and zinc, as well as 632 mg of potassium (18 %) and 0.44 mg of vitamin B6 (20%) (Rao and Annadana 2017). Furthermore, a potato with its skin has 3.5 grams of fiber, which is comparable to the fiber content of many other cereals such as wheat. Indirect benefits were also offered by potatoes.

Potatoes made good fodder for livestock (mainly cattle and pigs) and were relatively easy to store. Frequently, a sizable amount of the potato crop would be put to use as feed (Schott et al., 2000). Accordingly, potatoes also led to a rise in the consumption of meat and manure, which was a useful crop production input (Nunn and Qian, 2015). Small-scale farmers can use this crop in a system where multiple crops can be grown on the same piece of land each season because of its shorter growing season (Schott et al., 2000). Its primary purpose is to alleviate the temporary food scarcity that arises during the rainy season. Because it helps farmers get through the months of hunger, it is regarded as a transitional crop (Stevenson et al., 2019).

It is a very important food and cash crop in Ethiopia, especially in the high and mid altitude areas. (Degebasa, 2019). Potato has a promising prospect in improving the quality of the basic diet in both rural and urban areas of the country. Apart from consumption of boiled potatoes; it is now extensively used in the wide arrays of traditional stew preparations in both rural and urban areas. In this regard, potato is supplementing and substituting pulse crops that are commonly used for these purposes. Potato consumption has expanded to include chips, crisps and mixture preparations with other vegetables which are becoming popular in urban areas in recent years (Zaheer, and Akhtar, 2016).

## 2.4. Climatic Factors Influencing Potato Tuber Bulking

Environmental conditions play a crucial role in achieving optimal yields for potato crops.

To maximize yields, the crop must be grown in an environment that aligns with its specific climate and growing conditions. When a crop is well-suited to its environment, minimal adjustments are needed. However, unfavourable conditions can cause stress on the plants, leading to reduced yields (Decoteau, 1998). Pereira and Nova (2008) define potential yield as the maximum achievable yield for a given species or cultivar, under ideal conditions of solar radiation and other environmental factors. Meteorological factors directly impact crop productivity by influencing key physiological processes like transpiration, photosynthesis, and respiration, which in turn govern plant growth and development throughout the crop's life cycle (Pereira et al., 2008).

### 2.4.1. Temperature

The major environmental factor that affects the adaptation and productivity potato variety are heat stress, especially when temperature extremes coincide with critical stages of plant development (Levy, 1982). Cooler temperatures result in delayed maturity, which provides more time for the interception of solar radiation and conversion of intercepted radiation into dry matter (Pereira and Nova, 2008).

High temperatures adversely affect plant growth and tuber yield at least in three ways: through an overall reduction in growth, apparently in similar fashion to that produced by water stress; through a reduction in the photosynthetic rate and stomata resistance and an increase in dark respiration; through a reduction in rapid tuber enlargement and maturity (Tsoka et al., 2012).

Depending on the temperature regime and the crop, high temperatures can lead to low yields due to increased development rates and higher respiration. However, a short growth cycle can also be beneficial, e.g., to escape drought or frost, and the use of late-maturing cultivars could offset the effect of high development rates. Potato is grown in many different environments, but it is best adapted to cool climates such as tropical highlands with mean daily temperatures between 15 and 18oC as encountered in its center of origin. High temperatures can lead to low yields due to increased development rates and higher respiration. Higher temperatures favour foliar development and retard tuberization. In addition, heat stress leads to a higher number of smaller tubers per plant; lower tuber specific gravity with reduced dry matter content (Hijmans, 2003

According to Levy and Veilleux (2007) reported that potato crop are influence by high temperature on stress therefore haulm growth is accelerated, with assimilates partitioned more towards the haulm, photosynthesis is reduced and respiration is increased, tuber initiation is inhibited, tuber growth is inhibited, tuber disorders are more likely, tuber dormancy is shortened or abolished, tuber dry matter content may be reduced and tuber glycoalkaoid level may be raised. Mainly photoperiod and temperature which are regulate levels of endogenous growth substances. According to (Mihovilovich *et al*. 2009) reported that tuberization process of potato is controlled by environmental factors, Short days and cool night temperatures conducive for tuberization while long days and high night temperatures hinder the process. Among the plant growth regulators that have been used to study the potato tuberization phenomenon, GA3 has been reported to have a consistent delaying or inhibiting effect on potato tuberization (Jackson and Prat, 1996).

The optimum temperature for tuber initiation and growth ranges from 15-19$^{o}$c, higher temperature lower tuber yields and this is due to reduced participation of photosynthates to the tuber (Tadesse *et al*., 2001). Temperature from 20 to 29$^{o}$C leads to small tubers and temperature above 29$^{o}$C prevent tuber development (Girma *et al*., 2004). Potato has been produced in many tropical climates under high temperature stress, resulting in significant yield reduction and quality deterioration. This is attributed to the synthesis of high amounts of endogenous GA, that in turn delay or inhibit tuber initiation, reduce partitioning of the assimilates to the tubers, and hinder the synthesis of starch and tuber specific proteins (Tekalign and Hammes, 2005). Balamani *et al.* (1986) report tuberization to be promoted by short days and low temperature (<25$^{o}$C) whereas long days and high temperature delay or inhibit the process. As Modisane (2007) reported stolons and tuber formed at low temperature (22/14$^{o}$C) were higher than at higher temperature (27/17$^{o}$C) and rapid plant top growth at higher temperature (27/17$^{o}$C) than at low temperature (22/14$^{o}$C).

## 2.4.2. Moisture

Soil moisture is one of the most important factors which influence yield and quality of crops as it affects the chemical, biological and physical conditions of the soil. Water is necessary for growth, nutrient absorption, transpiration, biological reactions and many other life activities. The potential yield of crops is dramatically affected by the amount of water applied during the crop-growing season at a given region (Abdel-Ati *et al*., 2007; Pereira and Nova, 2008).

The amount of water capable of being held in a soil depends on soil texture (sand, silt, clay) and structure (loose, compacted). In a saturated soil, all spaces are filled with water. Drainage due to gravity progressively removes water from the pores of the soil. As more water is lost, so the forces holding it around the soil particles increase until equilibrium is reached. This stage is known as 'field capacity'. As the crop grows, water is extracted from the soil, and lost by transpiration from the leaves and evaporation from the soil and leaf surfaces. The combined effect is known as evapo-transpiration. The accumulated amount of water lost from the soil referred to as the Soil Moisture Deficit (Buckley *et al*., 2012).

Crop consumptive water use which is the amount of water transpired by the plants plus the water evaporated from the soil plus the fraction of water held by the plant tissues is determined. The amount of water retained by the plant metabolic activity is about 1% of the overall water taken up by the plants. Thus, in practical terms crop water consumption corresponds to crop maximum evapotranspiration, which included the evaporation e.g. from the soil surface. Potato evapotranspiration can be estimated using weather data and is the amount of water to be replenished during the growing season in order to assure potential tuber yields at a given site. Evapotranspiration varies according to meteorological conditions, plant and soil surface wetness, crop type, soil water status, and amount of crop cover leaf area index. The mainly meteorological parameters that affect evapotranspiration are solar radiation, relative humidity, ambient air temperature and wind speed (Pereira and Shock, 2006). Potato crop (example typical main crop potatoes grown in England) will use approximately 350 mm of water in an average growing season, although some of this can be provided by the soil, most must come in the form of rainfall and irrigation (Buckley *et al*., 2012). Bosnjak et al. (1997) found that tubers yield were highest in the 75-80% field capacity which was equivalent to a water requirement of 460-480mm / season. Ali (1993) showed that the seasonal water consumptive use by potato grown at Qalubia region, Egypt, varies between 300.4 mm and 419.3 mm for fall plantation, while in summer the values ranged from 443.4 mm to 626.9 mm. The variation is mainly due to climatic conditions and to the irrigation treatments, which were irrigated according to the local farmer practice. Gbadun *et al*. (2005) reported the average crop water requirements for rain-fed potato was 484mm and crop water use was within the rage of 320mm and 450 mm/season. They also observed evapotranspiration deficit range from 74.46 to 199mm and the crop water productivity of rainfall for potato varied from 0.712 kg/m3 to 3.07 kg/m3. These deficits are associated with low rainfall, midseason drought or early cessation of rainfall.

Lack of water is a most common stress in potato. The potato does not compost for drought period by prolonged growth. Even a short period of drought affects the yield, especially at tuber initiation. Dry soil causes reduction in number of stem, influence yield directly by restricting respiration and photosynthesis. Indirectly it leads to reduced evaporation from soil and leaves resulted to increased soil and plant temperature. Too much irrigation water or heavy rain falls also result to reduce emergence, poor root development and rotting of newly formed tubers. In rain fed potato production the amount of soil water at time of planting plus additional precipitation during the growing season is sometimes sufficient for potato production (Haverkort, 1982).

There is a very close association between heat and water stress, in fact it is very difficult to separate these two types of stress. Crop water use increases greatly with increasing temperature, resulting in rapid depletion of soil moisture. As the soil dries out a couple of things happen. First, the pores on the leaf responsible for evaporative cooling start to close resulting in an increase in leaf temperature. Evaporative cooling is also an important factor in soil temperature, so the drier the soil, the closer the soil temperature will be to the air temperature (Thornton, 2002).

The extent tuber yield and quality are adversely affected by drought will depend upon the severity, timing, and duration of water stress during the growing season. Water stress during the vegetative growth stage (begins at seed piece sprouting and extends to stolon formation) reduces leaf area, vine and root expansion, plant height, and delays canopy development. Water deficits during vegetative growth have also been shown to decrease the number of tubers set per plant, which then results in fewer and larger tubers at harvest. Water stress during tuber initiation can substantially reduce tuber yield and quality. The tuber bulking growth stage extends from the time tubers are about one-half inch in diameter to canopy senescence. Under ideal conditions, this growth stage is characterized by a relatively constant rate of increase in tuber size and weight. Interruptions in tuber growth by water stress often result in misshapen tubers having knobs, growth cracks, and irregular shapes characterized as “bottlenecks,” “dumbbells,” and other irregular curved shapes (King *et al.*, 2003).

## 2.5. Effects of Planting Date and Variety on Yield of Potato

Environmental factor influence potato growth such as temperature, rainfall and sunlight, are not controlled by growers. One of the most important grower controlled factors is the decision on when to plant. The risks associated with the wrong planting date are increased incidence of disease problems, slow or erratic emergence, frost damage, hollow heart, and slow canopy development (Khan *et al*., 2018)). Research result reported from southern India revealed that tuber yield of potato is significantly influenced by planting dates. Early planting of potatoes results in higher tuber yields, driven by increased tuber number, weight, plant height, leaf area index, and total dry matter production. These parameters decrease with delayed planting (Yenagi et al., 2005).

Studies indicate that planting time significantly affects potato yield, with early planting generally resulting in higher yields. Chain's research found that earlier spring planting at 500 m.a.s.l. increased yield due to improved light use efficiency, higher photosynthesis rates, and more tubers per plant. However, delayed planting at 750 m.a.s.l. boosted yield, while no significant effects were observed at 1200 m.a.s.l. In autumn, planting time had minimal impact on yield across elevations, though early planting often led to reduced plant stands (He et al., 1998).

Garba et al. (2005) also noted that early planting yielded better results, attributing late planting yield declines to temperature. As planting is delayed, crops may mature outside the optimal cold period, leading to excessive vine growth at the expense of tuber development. This competition for nutrients reduces tuber yield. Khan et al. (2011) observed the highest tuber yield (15.57 t/ha) from planting on September 24th, with subsequent yields decreasing as planting dates were delayed. Similar findings are seen in Tigray, where early planting aligns with improved yield outcomes due to optimal environmental conditions and growth balance.

Studies in Tigray, Ethiopia, have examined the impact of planting time on potato yields, highlighting the importance of early planting. Research by Gebregwergis et al. (2019) demonstrated that removing flower buds and earthing up potatoes 15 days after emergence significantly increased total tuber yield to 30.96 tons per hectare. Additionally, a study on potato genotypes under supplemental irrigation in Tigray found that early planting, combined with appropriate irrigation, enhanced marketable yield and water productivity. These findings underscore that early planting, along with proper agronomic practices; can substantially improve potato yields in Tigray's specific environmental conditions.

## 2.6. Potato Production in Ethiopia

Ethiopia is endowed with suitable climatic and edaphic conditions for quality potato production. About 70% of the available agricultural land are located at an altitude of above 1500 meters above sea level and receives an annual rainfall of more than 600 mm, which is suitable for potato production (FAO, 2014; Tekalign, 2003). The national average yield is 13.69 tons $ha^{-1}$ (CSA, 2014/15), which is lower than the world's average of 16.4 t $ha^{-1}$ (FAO 2014; FAOSTAT, 2014). The total land of potato in Ethiopia is about 67,361.87 ha with an annual production of 921,832.070 tons (CSA, 2014/15). Adoption of the crop by Ethiopian farmers occurred very gradually for several decades (Kidane-Mariam, 1980). Cultivation was limited to potato growing voluntarily in fields in the cold highlands until wider adoption of the potato occurred at the end of the nineteenth century in response to a prolonged famine (Gebremedihin et al., 2001). Potato production in Ethiopia has increased considerably through the twentieth century. In 1975, the area of potato cultivation was estimated at 30,000 hectares, with an average yield of approximately five tons per hectare (Gebremedihin et al., 2001). However, potato cultivation declined in the early 1980s due in part to widespread infection by late blight, Phytophthora infestans/ Phytophthora blight (Tesafahun and Boris 1985).

Gebremedihin et al. (2001) estimated that the area of cultivation had reached 50,000 hectares by the mid 1980's (an estimate still cited as of 2003 (FAOSTAT, 2010), but that by 2001, Ethiopia's potato area grew to 160,000 hectares, with average yields around eight tons per hectare. An upward trend in potato production might be due partly to the continuing increase in population and subsequent decline in the average size of farm holdings, hence the pressure for agriculture to become more labor intensive (Gebremedihin et al., 2001). The major problems of potato production in Ethiopia include drought, erratic rainfall, high temperature, frost and high disease and insect pressure; among those all constraints soil fertility is the one which limited its productivity (Temesgen, 2008).

Potato is ideally suited for places where land is limited and labor is abundant, conditions that characterize much of the developing countries. Moreover, potato is a highly productive crop. It produces more food per unit area and per unit time than wheat, rice and maize (Gebremedihin et al. 2001). Potato's short growth cycle also adds its value to securing food availability at the household level by improving farm productivity through permitting double crop production per annum. As Kabira et al. (2006) also indicated, potato plays an important role in national food and nutrition security, poverty alleviation, and income generation and provides employment in production to consumption continuum. In Tigray, Ethiopia total land allocated to potato production in 2016/17 Meher season was estimated at 622.2 ha with a total production of 50388 tones and total potato growers in the region were estimated at 16,564 households (CSA, 2017). The average yield was 8.1 t $ha^{-1}$, which is less than the national average 13.77t/ha and other regions of the country (CSA, 2016/17). This clearly shows the productive quality of potato and its promising prospect in feeding our alarmingly rising population against the dwindling natural resource base and global climate change ( EIAR 2016).

# CHAPTER THREE: MATERIAL AND METHODOLOGY

## 3.1 Description of the study area

The study was conducted at *Desta Berhe Farm,* located in the Raya Azebo District of the Tigray Regional State, approximately 132 kilometres from Mekelle. The site was chosen based on its potential for potato production, considering the area's suitability for crop cultivation and favourable environmental conditions. The experimental area was assumed to be uniform in terms of fertility and other key variables, with a pre-determined cropping history that allowed for a controlled and consistent analysis.

The farm is situated between 40° 20' E longitude and 8° 34' N latitude with an altitude ranging from 1500 meters above sea level. The climate of the area is characterized by an average annual temperature ranging from 16°C to 27°C, providing a relatively moderate environment for crop growth. The area receives rainfall ranging from 400 to 700 mm annually, which is conducive to the cultivation of a variety of crops, including potatoes (Gebremeskel et al., 2018). The soil is predominantly silt, with a pH value of 7, indicating a neutral soil environment, ideal for the growth of many crops, including potatoes.

## 3.2. Experimental Design and treatment

The field experiment was arranged in Randomized Complete Block Design (RCBD) with three replications. Three planting dates (October17, November 2 and November 17, 2023) and three potato varieties (*Belette, Gudane, & Jaleni*) were arranged in factorial combinations, and the experiment was comprised a total of nine (9) treatments. The potato varieties were selected for this experiment based their wider production by local farmers.

The gross plot size was 3m*3m (9 $m^2$) with spacing of 75 and 30 cm between rows and plants respectively. A distance of one meter was maintained between plots and two meters between blocks.

**Table 1.** Description of potato varieties used for the experiment

| Variety | Altitude (m.a.s.l) | Days required to Maturity | Amount of water required (mm) | Yield (qt/ha) on Farmer |
|---|---|---|---|---|
| Belette | 1600-2800 | 100-120 | 750-1000 | >266 |
| Gudane | 1600-2800 | 100-120 | 750-1000 | 210 |
| Jalene | >2400 | 100-110 | 500-850 | 400 |

**Sources** (MoANR, 2016)

## 3.3 Experimental procedures

Land preparation was carried out using tractor, as is customary among local farmers. The field was carefully levelled to ensure uniformity, and seedbeds were raised to prepare for planting. The experimental treatments were randomly assigned to each plot using the GenStat ($18^{th}$) randomization technique. Each treatment was represented once in each block (replication). For planting, medium-sized, well-sprouted potato tubers were sourced from Mekelle Tissue Culture. These tubers were selected for their quality and uniformity to ensure consistency in the experiment.

All agronomic practices, except for the specific treatment factors, were applied uniformly across all experimental plots, following the standard practices used by local farmers. This included applying the recommended fertilizer rates: 110 kg of Urea and 90 kg of Diammonium Phosphate (DAP) per hectare (EARO, 2004). Urea fertilizer application was done in a split application. Half of the Urea was applied at planting, while the remaining half was applied during the vegetative phase, approximately 40 days after planting. DAP was applied in full at the time of planting, and it was placed in the root zone of each potato plant or used as a side dressing.

Irrigation was managed manually, with equal amounts of water applied to each plot two times a week using furrow irrigation. To ensure proper moisture levels for optimal plant growth, the irrigation process was carried out until the soil reached field capacity, ensuring that the furrows became fully saturated and water began to run out of the targeted plots.

Weed control was managed through hand weeding, which was performed three times during the growing season. To promote healthy tuber development and protect the crop, earthening-up (mounding soil around the base of the plants) was done twice before flowering to encourage tuber bulking and once after flowering to prevent the tubers from being exposed to direct sunlight. This practice also helped to improve soil structure and water retention around the roots.

Overall, these practices were designed to ensure optimal growing conditions for the potato crop while maintaining consistency with local farming practices.

## 3.4. Data Collection

To determine the effect of planting date and varieties on yield and yield component of potato, relevant data on growth, yield and yield components were collected by randomly selecting six plants from the two harvestable middle rows of each plot as follows:

### 3.4.1. Growth parameters data and Field measurements

### 3.4.2. Potato phenology and growth parameters

**Days to 50% Emergence:** The days to 50% emergence were recorded through daily observations of the experimental plots. Emergence was considered to have occurred when the first visible signs of growth, such as the appearance of the shoot, were noticed in the majority of plants in each plot. Specifically, the number of days from planting to the point at which half of the plants in the plot had visibly emerged counted as described by Thornton, (2020).

To ensure accuracy, each plot was carefully observed, marking the date when the first plant was observed to have emerged and then continuing daily observations. Once half of the plants in a plot had visibly emerged, the total number of days from planting to this point was recorded as the days to

50% emergence for that plot. This process was repeated for all treatment plots to determine the emergence rate for each treatment under study as described by Veasey et al. (2007).

Days to 50% flowering were recorded by monitoring the experimental plots daily to track flowering progress. Flowering was considered to have occurred when 50% of the plants in each plot had at least one open flower. The number of days from planting to the date when half of the plants reached this stage was then recorded, as described by Niguse (2016)**.**

**Days to 90% Maturity:** Maturity was considered when 90% of the plants in each plot had yellowing leaves and the plants showed visible senescence of the haulms (the above-ground stems and leaves). This senescence indicated that the plant was reaching the final stage of growth, with the tubers fully developed and ready for harvest. The number of days from planting to this stage was then recorded as the "days to 90% maturity" for each treatment following the methods described by Gebremeskel et al. (2018).

**Plant height in (cm)**: plant height was measured from six randomly selected plants per plot. The measurement was taken from the soil surface at the base of the plant to the top-most growth point, which is typically the apical bud. A measuring tape or ruler was used to ensure precise measurements. Care was taken to ensure that each plant was standing upright during measurement to avoid inaccuracies caused by plant bending. The height of each plant was recorded, and the average height per plot was calculated as stated by Thornton, (2020).

### 3.4.3 Yield and yield component parameters

**Numbers of tubers per plant-** The number of tubers per plant was determined by counting the total number of tubers in six randomly selected plants per plot. The tubers were carefully dug out to avoid damage. After digging out the tubers, they were counted by hand, ensuring that all visible tubers were included. The count from each potato plant was recorded, and the average number of tubers per plant was calculated. This process was repeated for six plants to obtain a representative sample.

**Tuber diameter**: tuber diameter was measured to assess the size of the potatoes, with tubers greater than 3.5 mm in diameter considered as marketable. To measure tuber diameter six tubers were randomly selected and cleaned to remove soil. Using a calliper micrometre, the widest part of each tuber was measured to the nearest millimetre. The measurement was taken at the point of greatest diameter, typically the middle section of the tuber. The diameter of each marketable tuber was recorded, and the data was used to categorize the tubers into size classes. This method ensures precise and consistent measurements, which are important for determining marketability and evaluating tuber quality as stated by Niguse, (2016).

**Total tuber weight:** tuber yield was measured in plot wise by collecting all harvested tubers from each potato plant within the plot. After harvesting, the tubers were carefully weighed using a digital scale to ensure accurate measurements in kilograms (kg). The weight of tubers from each plant was recorded, and the sum was calculated for all plants in the plot. The yield was then converted to quintal per hectare as described by Negero (2017).

**Marketable tuber yield**: marketable yield was determined selecting tubers that were healthy and weighed 20 grams or more were considered marketable. These tubers were carefully harvested, cleaned, and weighed using a precise digital scale to obtain their total weight in kilograms per plot. To calculate the yield per hectare, the total weight in kilograms per plots was converted in hectare base. The result was then converted into quintals (qt) by dividing the total weight by 100 to accurate and reliable estimation of marketable tuber yield as described by Negero, (2017).

**Unmarketable Tuber yield:** unmarketable was measured by collecting tubers considered unmarketable. These included tubers with any signs of rot, disease, insect damage, deformed shape, or tubers whose diameter was less than 35 mm. Such tubers were carefully separated from the marketable tubers during harvesting. Each tuber, which fell into the category of unmarketable, was visually checked for any signs of decay or disease. The tubers were weighed on a digital scale to note their total weight in kilograms per plot. The total weight of unmarketable tubers from all the plants in the plot was calculated. The data was then converted to yield per hectare to make the weights more consistent and comparable, thus giving an accurate indication of the quantity of unmarketable tubers produced per area, which is highly important in determining crop quality and general production as stated by Niguse, (2016).

## 3.5. Data analysis

Data collected on potato growth, yield and yield components were analyzed using GenStat statistical software (version 18th). The assumptions of normality and homogeneity of variances were checked before carrying out the respective analysis to ensure the validity of the results. After these assumptions were confirmed, analysis of variance was conducted to detect any significant differences among treatment levels representing varieties and planting dates. ANOVA was used to point out if the variation in yield and its components observed is statistically significant. To further explore the differences between the treatments means, the LSD test at 5% probability was performed following the procedures described by Gomez and Gomez, (1984).

# CHAPTER FOUR: RESULT AND DISCUSSION

## 4.1. Effect of planting dates and variety on phenological and growth parameters of potato

### 4.1.1. Days to 50% Emergence

The results indicated that there was no significant variation among the studied potato varieties in terms of the number of days required to reach 50% emergence (Table 2) though there were slight observable variations between the varieties. This suggested that genetic factors related to the variety less influenced the speed of emergence. In contradiction with this, it has been reported a significant difference in days to emergence among potato varieties (Ebrahim et al., 2018). This contradiction could be due to difference in tested agro ecology and the size of tested varieties (Dash et al., 2018). On the other hand, previous studies have shown that varieties with different genetic backgrounds show similar growth rates, particularly in early stages of development (Gebreselassie et al., 2016). This would indicate that while the emergence patterns are similar across varieties, there are some subtle genetic or environmental factors contributing to the emergence rate (Naz et al., 2024). Similarly, varieties have similar response to germination determining factors. However, overall contribution emergence time to yield may not be significant within the context of these planting dates (Haile et al., 2015). Using a relatively large number of varieties would increase the chances of capturing high genetic variation for the mentioned traits.

Planting date had a highly significant effect ($P < 0.001$) on the days to emergence, days to flowering, and days to maturity (Table 2). The earliest emergence (9.4 days) was observed in plots planted on $2^{nd}$ November, while varieties planted on $17^{th}$ October showed the latest emergence (13.3 days). The difference between the earliest planting date ($17^{th}$ October) and the mid planting date ($2^{nd}$ November) was 3.9 days, which accounts about 41.5% faster emergence in the $2^{nd}$ November compared to planting date by $17^{th}$ November. The late planting date ($17^{th}$ November) had an intermediate emergence time of 11.5 days (Table 2).

**Table 1 . Mean squares for phonological, growth and yield- parameters of potato varieties under different planting dates**

| SV | DF | DTE | DTF | DTM | PHT | NTPP | ATW | TD | MTY | UNMY | TTY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rep | 2 | 0.7$^{ns}$ | 2.1ns | 30276 | 16.08 | 3.704 $^{ns}$ | 0.02938 $^{ns}$ | 3.752$^{ns}$ | 18.8$^{ns}$ | 101.37$^{ns}$ | 224.5$^{ns}$ |
| Variety(V) | 2 | 3.4$^{ns}$ | 14.3$^{ns}$ | 29576.$^{ns}$ | 32.29$^{ns}$ | 17.593** | 0.08829* | 2.83$^{ns}$ | 8228.8** | 63.81$^{ns}$ | 9115.8** |
| PD | 2 | 34.1** | 75.4** | 28876** | 34.49$^{ns}$ | 17.593** | 0.11689** | 32.408$^{**}$ | 125274.7** | 685.11** | 7863.6** |
| V*PD | 4 | 1.5$^{*}$ | 3.4ns | 30269.$^{ns}$ | 41.39$^{ns}$ | 2.315$^{ns}$ | 0.01314$^{*}$ | 0.731$^{*}$ | 1738.8** | 10.81$^{ns}$ | 1749** |
| Residual | 16 | 1.6 | 5.6 | 30120 | 36.89 | 2.620 | 0.01819 | 1.034 | 207.2 | 47.81 | 2957.2 |
| Total | 26 | | | | | | | | | | |
| CV | | 11.1 | 3.9 | 121.1 | 13.0 | 14.8 | 15.1 | 15.7 | 6.8 | 44.6 | 6 |

***Abbreviations:*** *DTE= days to emergency, DTF= days to flowering, DTM= days to maturity, PHT= plant height (cm), NTPP= number of tuber per plant, ATW = average tuber weight, TD= tuber diameter, UNMY =unmarketable tuber yield, LSD=least significances differences, NS= none significant difference, PD= planting date*

LSD=least significances differences, NS= none significant difference, PD= planting date CV= coefficient of variance, ** means highly significant effect while NS denoted no significant difference

This result suggested that environmental conditions associated with planting date, such as soil temperature, moisture availability, and photoperiod may influence the speed of seedling emergence. Planting date on the 2nd November was likely favourable conditions for seedling growth, which could be associated with moderate soil temperatures and more stable moisture levels. Conversely, earlier planting (17th October) may have been subjected to cooler temperatures that delayed germination, as noted in similar studies by Rykaczewska, (2015) who found that lower soil temperatures slow down the germination process in many crops. Similarly, delayed maturity has reported from earlier planting dates of potato varieties (Haile et al., 2015).

The interaction of variety and planting date significantly (P = 0.045) influenced days to emergence ( *Belete* variety planted on 17th October was the latest to emerge and took about 12.33 days. This was longer compared to other later planting dates (9.67 and 10.67 days) for November 2nd and 17th planting dates respectively. *Jalenne* variety was the late to emerge, especially in the October 17th planting date, which took about 14.67 days. The percentage difference in days to emergence from 17th October to 2nd November for *Belete* and *Gudena* was, 22.2% and 30.8%, respectively; this illustrated the impact of planting date was notable on the speed of emergence.

## 4.1.2. Days to 50% Flowering

Potato varieties showed no significant difference in their days to flowering (Table 2). This is consistent with previous research, which indicated that environmental factors often have a greater influence on crop phenology than genetic factors, particularly in response to temperature and photoperiod (Nakamichi, 2015). The results also show inconsistency with those reported by Alemayehu et al. (2018), who found significant variation among potato varieties for their days to 50% flowering and 70% maturity. This inconsistency could be due to geographical location has a considerable influence on flowering and maturity traits of potato varieties.

On the other hand, planting date had a highly significant ($P < 0.001$) effect on the days to flowering of potato varieties (Table 2). Potatoes planted on the 2nd of November flowered earlier (57.0 days), while varieties planted on the 17th of October took the longest (61.78 days) to flower. The difference between the first and second planting dates for flowering was 4.78 days, representing about 8.2% delay in flowering for the October 17th planting compared to the November 2nd planting. Potatoes planted on the 17th of November flowered in 62.2 days, slightly later than those planted on November 2nd, but earlier than those planted in mid-October. The delay in flowering for the earlier planting date could be attributed to environmental factors, such as lower temperatures at the start of the growing season, which likely slow down plant development. These results are consistent with findings by Zhang et al. (2022), who noted that lower early-season temperatures delay flowering in many crops. Furthermore, the delay in flowering time for October 17th likely reflects the slower accumulation of thermal units, which are essential for the transition from vegetative to reproductive growth stages (Naz et al., 2024). Therefore, planting dates significantly affected flowering time.

There were also no statistical differences in days to flowering among the tested potato varieties, indicating their genetic difference did not significantly affect flowering length.

In nutshell, while variety had a minimal effect on flowering time, planting date played a more crucial role in determining the days to flowering. The environmental conditions associated with the planting dates, particularly temperature might influence flowering timing in potato varieties (Alemayehu et al., 2018; Zhang et al., 2022).

### 4.1.3. Days to 90%Maturity

There was no statistically significant difference among the tested potato varieties on their days to maturity (Table2). This insignificant difference may suggest that varieties exhibited similar response in maturity timing. Besides, this may be due the varieties have similar genetic traits in common or the expression of phenological traits are highly influenced by environmental factors (Haile et al., 2015; Zhang et al., 2022). In parallel, environmental factors influencing maturity times who reported that varieties with early-maturing traits tend to complete their growth cycles more quickly under favourable conditions (Chang et al., 2020). Therefore, while slight trends were observed, the lack of significant differences suggests that environmental factors play a larger role in influencing maturity timing, with varieties responding similarly under favourable conditions.

Planting date had a highly significant effect on potato days to maturity ($P < 0.001$) (Table 2). Early planting date (17$^{th}$ October) resulted in prolonged maturity time (113.9 days), while plots planted on 2$^{nd}$ November matured earlier (107.3 days). Similar maturity time (107.6 days) was observed from planting dates (2$^{nd}$ and 17$^{th}$ November). The difference between the first and the second planting dates were 6.6 days, demonstrating planting date on 2$^{nd}$ November matured earlier by 5.8% compared to plating dates on 17$^{th}$ October. This can be due to the differences in temperature accumulation during the growing season and variation in day length from October to November. Later planting dates (2$^{nd}$ November and 17$^{th}$ November) might be benefited from longer day lengths and higher temperatures, which accelerate the rate of development and shorten the time to maturity (Haverkort, 2007). In addition, it has been noted that later planting allows crops to mature faster, likely due to the accumulation of more heat units, a critical factor for crops in temperate and subtropical climates (Bhattacharya, 2022; Wurr et al., 2002). Generally, later planting dates, particularly in early November, resulted in faster potato maturation due to increased heat accumulation and longer day lengths.

There was no significant interaction effect of variety and planting dates, and main effect of variety on days to maturity, pointing out that planting dates did not affect the maturity trends of potato varieties. Implying other factors such as genotype or environmental conditions may have had little effect on maturity time (Bhattacharya, 2022; Haverkort, 2007). Similarly, as noted by Chang et al. (2020), the early maturing traits of some varieties would be expected to attain maturity under favourable conditions. This observation implies that maturity is not greatly influenced by the planting date per se across potato varieties.

### 4.1.4. Plant Height

The potato varieties did not show a significant difference in plant height (Table 2). These results contradicted with previous studies by Fantaw et al. (2019) who reported that the tallest plant height (58.81 cm) from *Belete* variety compared to other landrace varieties. This indicates the possibility that while overall trends may not be significant, specific varieties can exhibit superior growth under optimal conditions. Similarly, it has been emphasized that environmental factors like soil quality, temperature, and light can significantly affect plant height other than genetic difference (Bhattacharya, 2022; Haverkort, 2007).

Similarly, planting date did not significantly affect potato plant height. This suggested that variation in planting date might not favour better plant growth. Therefore, none statistical significance noticed ,could be due to the environmental conditions during each planting period were not extreme enough to cause significant differences in plant height, as reported by Chang et al. (2020). Additionally, there was no significant interaction between planting dates and variety on potato plant height (Appendix table12), meaning that the planting dates did not have a noticeable effect on plant height.

The none significant difference among planting dates and varieties agreed with the findings reported by Ahmed et al. (2017) who stated that plant height had less increment with early planting date for potato growth and yield parameters. On the other hand, significant increases in potato plant height with late planting dates were reported by Haile et al. (2015). This suggested that early planting allows potatoes to take advantage of optimal environmental conditions, promoting better growth, and late planting allows plants to benefit from longer day lengths and higher temperatures, leading to increased growth. This argument could be due to differences in temperature and soil quality at the location of this study compared to others, which may have minimized the impact of planting date and variety on potato plant height.

**Table 2.** Effect of planting dates and variety on the Potato phenological and growth parameters

| Variety | **DTE** | **DTF** | **DTM** | **PHT** |
|---|---|---|---|---|
| **Belete** | 10.89 | 58.89 | 108.4 | 48.62 |
| **Gudena** | 11.33 | 60.89 | 109.2 | 46.98 |
| **Jaleni** | 12.11 | 61.22 | 111.1 | 44.84 |
| **LSD$_{(0.05)}$** | NS | NS | NS | NS |
| **CV (%)** | 11.1 | 3.9 | 2.1 | 13 |
| P value | 0.15 | 0.11 | 0.076 | 0.43 |
| Planting dates | | | | |
| **PD1** | $13.3^{c}$ | $61.^{78b}$ | $113.9^{a}$ | 47.88 |
| **PD2** | $9.4^{a}$ | $57^{a}$ | $107.3^{b}$ | 44.56 |
| **PD3** | $11.5^{b}$ | $62.2^{b}$ | $107.6^{b}$ | 48.01 |
| **LSD$_{(0.05)}$** | 1.268 | 2.376 | 2.35 | NS |
| **CV (%)** | 11.1 | 3.9 | 2.1 | 13 |
| **P value** | <.001 | <.001 | <.001 | 0.43 |

***Abbreviations:*** *DTE= days to emergency, DTF= days to flowering, DTM= days to maturity, PHT= plant height (cm), CV= coefficient of variance, LSD= least significant difference, NS=none significance difference, and means followed by the same letters show non-significance, while means with different letter are denoted as significantly different.*

*PD1= planting date on 17th October, PD2= planting date on 2nd November, and PD3= planting date on 17th November.*

**Table 3.** Interaction effect of variety and plant dates on potato phenological and growth parameters

| | DTE | | | DTF | | | DTM | | | PH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Planting dates | | | | | | | | | | | |
| Variety | **PD1** | **PD2** | **PD3** | **PD1** | **PD2** | **PD3** | **PD1** | **PD2** | **PD3** | **PD1** | **PD2** | **PD3** |
| **Belete** | 12.33 $^{bc}$ | 9.67a | 10.67$^{ab}$ | 61.00 | 55 | 60.6 | 113.0 | 106.7 | 105.6 | 45.67 | 52.43 | 47.77 |
| **Gudena** | 13.00 $^{cd}$ | 9.0a | 12.00$^{bc}$ | 61.00 | 58 | 63.67 c | 112.7 | 106.7 | 108.3 | 50.00 | 44.33 | 46.60 |
| **Jalenne** | 14.67 $^{d}$ | 9.67a | 12.00$^{bc}$ | 63.33 | 58 | 62.33 | 116 | 108.7 | 108.7 | 41.20 | 43.67 | 49.67 |
| LSD | | 2.1 | | | NS | | | NS | | | NS | |
| CV (%) | | 11.1 | | | 3.9 | | | 2.1 | | | 13 | |
| P value | | 0.045 | | | 0.66 | | | 0.75 | | | 0.38 | |

***Abbreviations:*** *DTE= days to emergency, DTF= days to flowering, DTM= days to maturity, PHT= plant height, LSD= least significant difference,*

*PD1= planting date on 9th October, PD2= planting date on 24 November, PD3= planting date on 9th November, LSD= least significant difference, CV= coefficient of variance, means with same letters denoted no significant difference between them, while means with different letters denoted statistically difference.*

## 4.2. Effect of planting date and variety on yield and yield related potato parameters

### 4.2.1 Total Number of Tubers per Plant

The result revealed that highly significant (*P<0.01*) main effect of variety and planting date on potato total number of tubers (Table 4). The highest number of tuber per plant (12.44) was recorded from the variety *Belete* while the lowest number (9.67) of tuber was counted from the *Jalenni* variety (Table 4). This could be due to the variation in genetic potential among the potato varieties. In line with this result, Mihovilovich et al. (2015) reported the potential tuber number that can be successfully produced by a plant varies with the genotype.

Among the three planting dates, the highest number of tubers (12.4) was recorded for the late planting on 17th November, while the lowest (9.6) was observed for the earlier planting date on $17^{th}$ October. This trend suggests that later planting, benefiting from longer day lengths and higher temperatures can enhance tuber formation, as supported by Masarirambi et al. (2012) and Ahmed et al. (2017).

The interaction of Variety and planting date was significant on numbers of tubers per plant. *Belete* outperforms across all planting dates with an average of 12.00 tubers per plant each at $17^{th}$ October and $2^{nd}$ November, and 13.33 tubers at $17^{th}$ November planting date (Table 5). In contrast, tuber production increased with later planting dates for both *Gudena* and *Jalenne* varieties. For *Gudena*, tuber production improved by 33.3% from October 17th to November 17th, while *Jalenne* variety showed increment by 50%, indicating that later planting dates enhanced tuber yield. Similarly, it has been indicated that planting date and variety interaction influenced tuber number, and *Belete* reported as the most stable performer across all dates (Alemayohu et al., 2018).

Extended planting date increased the numbers of tuber per plant in all potato varieties. Similarly, the highest number of tuber per plant has reported from *Belete* variety compared to other local varieties (Alemayohu et al., 2018). In contradiction with the current result, Vishwas et al. (2020) reported higher number of tuber per plant (13.84) from early planting (10th July) of potato. These variations could be due to the result of differences in the time of planting seasons and temperature which probably had the greatest effects in tuber formation (Singh et al., 2022).

In general, potato tuber production increased in later dates of planting in all the tested potato varieties. However, *Belete* consistently outperformed the other varieties; hence, the evidence is supportive of both factors with the important influence of variable weather conditions on potato tuber yield.

**Table 4.** Effect of planting date and variety on potato yield and yield related parameters

| **Variety** | **NTPP** | **ATW** | **TD** | MTY | **UTY** | TTY |
|---|---|---|---|---|---|---|
| **Belete** | 12.44$^{b}$ | 0.98$^{b}$ | 7.05 | 246.8 a | 17.4 | 264.2$^{b}$ |
| **Gudena** | 10.78 $^{a}$ | 0.91$^{ab}$ | 6.3 | 200.7$^{b}$ | 12.4 | 212.5$^{a}$ |
| **Jaleni** | 9.67 $^{a}$ | 0.78$^{a}$ | 5.9 | 189.8$^{b}$ | 16.5 | 206.3$^{a}$ |
| $LSD_{(0.05)}$ | 1.6 | 0.13 | **NS** | 14.54 | NS | 6 |
| CV (%) | 14.8 | 15.1 | 14.6 | 6.8 | 44.6 | 13.5 |
| P value | 0.008 | 0.012 | 0.095 | 0.001 | 0.28 | 0.001 |
| | | **Main effect of planting date** | | | | |
| **PD1** | 9.67$^{a}$ | 0.89$^{ab}$ | 7.66$^{a}$ | 215.9$^{b}$ | 10.3$^{b}$ | 231.4$^{b}$ |
| **PD2** | 10.78$^{a}$ | 1.01$^{b}$ | 7.44$^{a}$ | 239.7$^{a}$ | 10.5 $^{ab}$ | 255.2$^{c}$ |
| **PD3** | 12.4$^{b}$ | 0.78$^{a}$ | 4.27$^{b}$ | 165.4$^{c}$ | 16.5$^{a}$ | 196.4$^{a}$ |
| LSD(0.05) | 1.61 | 0.13 | 1.01 | 14.54 | 6.8 | 13.5 |
| CV (%) | 14.8 | 15.1 | 14.6 | 6.8 | 44.6 | 6 |
| P value | 0.008 | 0.0037 | 0.001 | 0.001 | 0.001 | 0.001 |

***Abbreviations:*** *NTPP= number of tuber per plant, ATW = average tuber weight, TD= tuber diameter, UTY =unmarketable tuber yield, LSD=least significances differences, NS= none significant difference, PD1= planting date on 17$^{th}$ October, PD2= planting date on 2$^{nd}$ November, PD3= planting date on 17$^{th}$ November, LSD= least significance difference, CV= coefficient of variance, means with same letters denoted no significant difference between them, while means with different letters have statically difference.*

**Table 5.** Interaction effect of variety and planting date on number of tubers per plant by count

| Variety | Planting dates | | |
|---|---|---|---|
| | PD1 | PD2 | PD3 |
| Belete | 12.00$^{c}$ | 12.00 $^{c}$ | 13.33$^{c}$ |
| Gudena | 9.00 $^{ab}$ | 11.33 $^{bc}$ | 12.00$^{c}$ |
| Jalenne | 8.00 $^{a}$ | 9.00 $^{ab}$ | 12.00$^{c}$ |
| LSD$_{(0.05)}$ | | 2.8 | |
| CV (%) | | 14.6 | |
| P value | | 0.049 | |

***Abbreviations:*** *PD1= planting date on 17$^{th}$ October, PD2= planting date on 2$^{nd}$ November, PD3= planting date on 17$^{th}$ November, LSD= least significance difference, CV= coefficient of variance, means with same letters denoted no significant difference between them, while means with different letters have statically difference.*

## 4.2.2 Average tuber weight

The main effect of variety and planting date on potato average tuber weight was highly ($P < 0.01$) significant (Table 4). The highest average tuber weight (0.98 kg) was recorded from *Belete* variety followed by *Gudena* (0.91 kg), while the minimum average tuber weight (0.78 kg) was recorded from *Jalenne* (Table 4). Similarly, Bilate and Mululalem (2016) have reported a highly significant difference among improved potato verities. In addition, *Belete* and *Gudena* varieties have been confirmed as best varieties (Bekele and Haile, 2019). This infers that, potato variety plays a critical role in determining the average tuber weight, with some varieties like *Belete* and *Gudena* outperformed *Jalenne* variety. This indicated that selecting the right potato variety is crucial for optimizing yield, especially in terms of tuber size.

Regarding planting dates, the highest average tuber weight (1.01 kg) was achieved with planting on 2$^{nd}$ November, while the lowest (0.78 kg) was observed with late planting on November 17$^{th}$. Delayed planting date, particularly in November 17$^{th}$, significantly reduced the average tuber weight (Table

4).These findings are consistent with previous studies that highlighted the unfavourable effect of delayed planting on potato tuber weight (Bagheripour et al., 2012; Chang et al., 2020; Dehdar et al., 2012). The implication of these results is that timing of planting is crucial for optimizing potato yield, as earlier planting led to significantly larger potato tubers.

Table 6. Interaction effect of variety and planting date on average tuber weight (kg) of potato varieties

| | Planting dates | | |
|---|---|---|---|
| Varieties | PD1 | PD2 | PD3 |
| Belete | 0.98$^{bcd}$ | 1.13$^{d}$ | 0.8267$^{abc}$ |
| Gudena | 0.95$^{abcd}$ | 1.03$^{cd}$ | 0.7633$^{ab}$ |
| Jalenne | 0.733$^{a}$ | 0.8$^{abc}$ | 0.76$^{ab}$ |
| LSD | | 0.23 | |
| CV | | 15.1 | |
| P value | | 0.038 | |

***Abbreviations:*** *PD1= planting date on 17th October, PD2= planting date on 2nd November, PD3= planting date on 17th November, LSD= least significance difference, CV= coefficient of variance, means with same letters denoted no significant difference between them, while means with different letters have statically difference.*

The interaction effect of variety and planting date was significant affected average tuber weight potato varieties under various planting dates (Table 6). The maximum tuber weight (1.13 kg) was recorded from Belete variety planted on 2nd November which had increased by (0.98 kg) or 14.7% from its first planting date (Table 6). In contrast, the minimum tuber weight (0.733 kg) was recorded for the *Jalenne* variety across all planting dates, with only a 9.1% increase in tuber weight from the October 17th planting (0.733 kg) to the November 2$^{nd}$ planting (0.8 kg). The tuber weight for all varieties was lower at 17th November, with marked decreases in *Belete* and *Gudena* at 26.2 and 25.4%, respectively, from 2$^{th}$ planting date. Overall, the result indicated that, the 2nd November planting date consistently yielded the highest tuber weights for all varieties. Similarly, planting date on November 17th has been reported to be the best conducive planting date to enhance potato varieties' yield (Singh et al, 2022). These results emphasized the role of timely planting and variety selection for optimizing tuber weight, with earlier planting and the *Belete* variety demonstrated the best performance.

### 4.2.3 Tuber diameter yield (mm)

The analysis of variance indicated that the main effect of planting date and, the interaction effect of planting date and variety had resulted significant differences in potato tuber diameter (Appendix table 13). The largest tuber diameter (7.6 cm) was recorded for the earlier planting on 17th October, while the smallest diameter (4.2 cm) was observed for the later planting on 17th November (Table 4). This result confirmed that earlier planting may provide a more favourable environment for tuber growth, probably due to cooler temperatures during the early growth stages, allowing tubers to develop more fully before temperatures rise. In contrast, later planting may expose potato to higher temperatures during tuber bulking, which could limit tuber size (Kim and Lee, 2019). This signifies the critical role of planting date in influencing tuber development and overall yield.

The interaction effect of variety and planting date on potato tuber diameter revealed the largest tuber diameter (8.5 mm) was measured from *Belete* planted in the $2^{nd}$ November which increased tuber diameter by 5.9% compared to $17^{th}$ November planting date (Table 7). This suggested that delaying the planting date from October 17th to 2nd November enhanced the tuber diameter for *Belete* variety. In contrast, *Gudena* had the largest tuber diameter (8.1 mm) on the October 17th planting date. However, its diameter decreased by 1.0 mm (11.6%) compared to the November 2nd planting, indicating that later planting dates negatively affected tuber diameter. Similarly, *Jalenne* exhibited relatively stable tuber diameters, with 7.1& 6.6 mm planted at October $17^{th}$ and November $2^{nd}$ respectively, indicating a decrease of tuber diameter by 7.0% (Table 7). All varieties planted at 17th November showed a substantial reduction in tuber diameter.

Table 7**.** Effect of variety and planting date on potato tuber diameter *mm*

| | Planting dates | | |
|---|---|---|---|
| Varieties | PD1 | PD2 | PD3 |
| Belete | 7.800 ab | 8.5b | 4.87 ab |
| Gudena | 8.100b | 7.16ab | 3.9 a |
| Jalenne | 7.100ab | 6.6ab | 4.06 ab |
| LSD $_{(0.05)}$ | | 1.76 | |
| CV (%) | | 14.6 | |
| P value | | 0.035 | |

***Abbreviations:*** *PD1= planting date on 17th October, PD2= planting date on 2nd November, PD3= planting date on 17th November, LSD= least significance difference, CV= coefficient of variance, means with same letters denoted no significant difference between them, while means with different letters have statically difference.*

*Belete* variety decreased tuber diameter by 42.4% comparing tuber diameter recorded at 2nd November planting date. *Gudena* and *Jalenne* also showed significant reductions with diameters of 3.9 & 4.06 mm (45.7 & 38.7%) reductions across all planting dates, respectively (Table 7). These results suggested that, later planting dates, especially in mid-November, had a significant negative impact on potato tuber diameter. Therefore, earlier planting is preferable to optimize tuber size across varieties. Similar findings have been reported by Singh et al. (2022) who stated that planning dates delayed over mid-November significantly reduced potato tuber weight.  This claim may be due to the delayed planting after mid-November in Ethiopia results in unfavourable weather conditions that could reduce potato tuber weight (Gebremeskel et al., 2018, Fantaw et al., 2019).

To sum up, earlier planting (October 17$^{th}$ and November 2$^{nd}$) improved potato tuber diameter and delaying planting to mid-November resulted in significant reductions in tuber size across all tested potato varieties, underscoring the significance of early planting for optimal tuber development.

### 4.2.4. Total tuber yield (Quintals per hectare)

Total tuber yield was highly significantly (*$P < 0.01$*) affected by both the main and interaction effects of variety and planting date (appendix table 13). The highest total tuber yield (255 q ha$^{-1}$) was obtained from the planting date on 2$^{nd}$ November, while the lowest yield (196 q ha$^{-1}$) was harvested from the early planting date. Among the tested potato varieties, *Belete* produced the highest yield (264 q ha$^{-1}$), while *Jalenne* yielded the least (206 q ha$^{-1}$) (Table 4). This variability in yield among planting dates could be attributed to favourable climatic conditions during the 2$^{nd}$ November planting. Additionally, *Belete* may have a genetic advantage, with the ability to produce rapid top growth and form larger, more numerous tubers per plant. This highlights the importance of both planting date and variety selection in optimizing potato yield, as supported by previous research on climate and variety performance (Feleke et al., 2019).

Concerning to their interaction, the highest total tuber yield (302.8 q ha$^{-1}$) was harvested from the *Belete* variety planted on the 2$^{nd}$ November. Additionally, *Belete* variety was the highest-yielding cultivar during early planting (Table 8). High-yielding potato varieties are highly desirable for successful cultivation at optimal planting dates (Gotame et al., 2021). Potato *Gudena* variety, planted at earlier dates, showed the highest total tuber yield and marketable tubers, while *Jalenne* performed best in early November compared to October 17th and November 17th, with yields of 249.2, 187.1, and 182.5 q ha$^{-1}$, respectively.

These results agree with Kasa and Woldegiorgis (2000), who reported increased yield attributed to higher tuber numbers and size. Early planting allows tubers to receive optimal moisture and temperatures, leading to higher yields, as supported by Kim et al. (2017). Conversely, water stress and early senescence can shorten the growing season, resulting in lower yields (Keleta et al., 2018; Shiri-e-Janagard et al., 2009). In accordance with this, it has been stated decreased yields in late plantings due to higher disease incidence and other abiotic stress exposure (Tesfaye and Anteneh, 1999; Tesfaye et al., 2006).

Therefore, identifying the interaction between planting dates, climatic conditions, and variety characteristics is crucial for achieving the highest possible yield, and ensuring sustainable and profitable potato farming.

Table 8**.** Effect of variety and planting date on potato total tuber yield (quintal per hectare)

| | Planting dates | | |
|---|---|---|---|
| Varieties | PD1 | PD2 | PD3 |
| Belete | 273.6[a] | 302.8[a] | 216.3[a] |
| Gudena | 233.5[b] | 213.6[c] | 190.4[b] |
| Jalenne | 187.1[c] | 249.2[b] | 182.5[c] |
| LSD | | 23.53 | |
| CV | | 6.0 | |
| P value | | 0.001 | |

***Abbreviations:*** *PD1= planting date on 17th October, PD2= planting date on 2nd November, PD3= planting date on 17th November, LSD= least significance difference, CV= coefficient of variance, means with same letters denoted no significant difference between them, while means with different letters have statically difference*

## 4.2.5. Marketable Tuber Yield (quintal per hectare)

The main and interaction effects of variety and planting date had a highly significant impact on marketable tuber yield ($P < 0.01$) (Appendix table 13). Among the three planting dates, potatoes planted on 2nd November produced the highest marketable yield of 239 q ha$^{-1,}$ while the lowest marketable yield of 165 q ha$^{-1}$ was obtained from the later planting on November 17th (Table 4). This suggested that the early November planting benefited from favourable environmental conditions, promoting better tuber development. In addition, when comparing the tested varieties, *Belete* produced the highest marketable yield of 246 q ha-1, while *Jalenn*e yielded the lowest (189 q ha$^{-1}$)

marketable yield (Table 4). These findings indicated that both planting date and variety selection play crucial roles in optimizing marketable potato yield.

The highest marketable yield (290.4 q $ha^{-1}$) was obtained from the *Belete* variety planted on November 2nd while the lowest yield (156 q $ha^{-1}$) was recorded from *Jalenne* planted late on November 17th (Table 9). Delayed planting, reduced marketable tuber yields of the tested potato varieties except *belete*. This variation could be attributed to genetic differences among potato varieties and the influence of environmental factors on tuber bulking. The duration and rate of tuber bulking vary by variety and are depending on environmental conditions (Levy, 2007). Therefore, earlier planting led to higher marketable yields, likely due to the extended growing period available for tuber development. Earlier-planted potatoes might be benefited from prolonged exposure to optimal moisture and temperature conditions, which contributed to increased marketable yields (Kim et al., 2017).

These findings are supported by Haile et al. (2015) who concluded that, delayed planting reduces potato marketable yield due to unfavourable climatic conditions affecting tuber growth. Additionally, Kim et al. (2017) and Keleta et al. (2018) noted that delayed planting adversely affects marketable yield due to suboptimal conditions for tuber development. This could be as result of planting in mid-October provided the maximum duration of optimal temperatures and soil moisture, promoting vigorous vegetative growth, prolonged maturation, and increased photosynthesis, which enhanced tuber size and marketable yield.

To recapitulate, planting on November 2nd, substantially increased marketable yields by enhancing favourable growing conditions. Therefore, earlier planting is the ideal time to enhance potato growth and leading to higher marketable yields.

Table 9. Interaction effect of planting dates and varieties on potato marketable yield (q $ha^{-1}$)

| | Planting dates | | |
|---|---|---|---|
| Varieties | PD1 | PD2 | PD3 |
| Belete | $259.4^{a}$ | $290.4^{a}$ | $190.1^{a}$ |
| Gudena | $228.3^{b}$ | $206.4^{c}$ | $167.5^{b}$ |
| Jalenne | $175.8^{c}$ | $236^{a}$ | $156^{c}$ |
| LSD | | 24.92 | |
| CV (%) | | 6.8 | |
| P value | | 0.001 | |

***Abbreviations:*** *PD1= planting date on 17th October, PD2= planting date on 2nd November, PD3= planting date on 17th November, LSD= least significance difference, CV= coefficient of variance, means with same letters denoted no significant difference between them, while means with different letters have statically difference.*

### 4.2.6. Unmarketable tuber yield

Unmarketable tuber yield was significantly affected by the main effect of planting date ($P < 0.01$), indicating that the timing of planting influenced the proportion of non-marketable tubers. However, the main effect of variety and the interaction effect between variety and planting date were non-significant (table 4). None significant variations among varieties in non-marketable yield indicated that the tested potato varieties displayed similar genetic responses in terms of tuber quality. This implies that environmental factors, particularly the planting date, may play a more dominant role in determining the proportion of unmarketable tubers, rather than varietal differences.

Higher non-marketable yield (16.5q $ha^{-1}$) was observed from late planting ($17^{th}$ Novemebr), while the lowest non-marketable yield (10.3q $ha^{-1}$) was obtained from the earlier planting date ($17^{th}$ October) (Table 10). The higher unmarketable yield from late planting date may be due to the presence of a greater number of smaller-sized tubers that reduces the market value of tubers (Kumar et al., 2007) or there may be tuber quality deteriorating biotic and abiotic stresses. Similarly, Das et al. (2014) emphasized that early planting resulted in better overall potato tuber quality, with fewer non-marketable tubers. Moreover, Keleta et al. (2018) observed that the interaction between variety and planting date did not significantly affect the non-marketable yield; suggesting that the planting date had a stronger influence than varietal difference.

Table 10 . Effect of variety and planting date on potato unmarketable yield

| Variety | Planting date | | |
|---|---|---|---|
| | PD1 | PD2 | PD3 |
| Belete | 19.20 | 16.97 | 36.23 |
| Gudena | 10.53 | 12.17 | 34.40 |
| Jalenne | 16.23 | 17.37 | 37.00 |
| LSD | | NS | |
| CV | | 44.6 | |
| P value | | 0.91 | |

***Abbreviations:*** *PD1= planting date on 17th October, PD2= planting date on 2nd November, PD3= planting date on 17th November, LSD= least significance difference, CV= coefficient of variance, means with same letters denoted no significant difference between them, while means with different letters have statically difference.*

These findings suggest that while planting date played a crucial role in determining the yield of non-marketable tubers, genetic differences among potato varieties did not significantly affect marketability. Thus, selecting the optimal planting date is vital to improve tuber quality and marketable of potato.

Late planting increases unmarketable yield, while early planting generally results in better tuber quality, emphasizing the importance of optimizing planting dates for improved outcomes.

## 4.3. Correlation coefficient among potato phenological, growth, yield and yield related parameters

The correlation analysis revealed strong relationships among phenological, growth, yield, and yield components in potato varieties (Table 11). Strong positive (**r = 0.57** & **r = 0.59**) correlation was observed between days to emergence, days to flowering, and days to maturity; suggesting earlier emergence is associated with earlier flowering and maturity. Similarly, strong association between early emergence and faster crop development has been reported by Li et al. (2021). Studies have also shown that early-emerging varieties tend to have shorter growing seasons, potentially leading to smaller tubers due to limited time for tuber expansion (Kumari, 2020). In addition, a according to Ali et al. (2015), early planting leads to earlier flowering which can positively affect marketable yield. Thus, the correlation between phenological traits and tuber yields positively associated with development and the potential yielding of potato varieties.

Besides, strong (**r = 0.5**) positive correlation was shown between plant height and the number of tubers per plant; suggesting taller plants tend to have more tubers. This finding is supported by studies that emphasized the positive relationship between plant height and tuber production. In line with this, an increase in plant height was associated with higher tuber numbers in potatoes (Khayatnezhad et al., 2011). This may be due to wider leaf area and photosynthetic capacity, which could eventually, supports higher tuber formation. Likewise, plant height is often positively correlated with clove number per bulb, as taller plants may have more extensive root systems that support more cloves (Kumari, 2021).

The moderate negative correlation (**r = -0.49**) between the number of tubers per plant and days to maturity suggested that as the number of tubers per plant increases, the time required for the plant to reach maturity tends to decrease or vice versa. This could imply that varieties with higher tuber numbers may mature earlier, potentially due to earlier resource allocation to tuber formation rather than continued vegetative growth. Similarly, strong positive correlation (**r = 0.67**) between average tuber weight and total tuber yield indicated that larger individual tubers contribute significantly to the overall yield. This implies that improving tuber size could directly enhance total yield in potato varieties (Lamboro et al., 2014).

**Table 11 . Correlation coefficient (r) among phenological, growth, yield and yield components of potato varieties under different planting dates**

| | DTE | DTF | DTM | PH | NTPP | ATW | TD | MTY | UMTY | TTY |
|---|---|---|---|---|---|---|---|---|---|---|
| **DTE** | 1 | | | | | | | | | |
| **DTF** | 0.57** | 1 | | | | | | | | |
| **DTM** | 0.59** | 0.41** | 1 | | | | | | | |
| **PH** | 0.19 ns | -0.02 ns | -0.16 ns | 1 | | | | | | |
| **NTPP** | -0.25 ns | -0.15 ns | -0.49* | 0.50** | 1 | | | | | |
| **ATW** | -0.3 ns | -0.59** | -0.23 ns | 0.40* | 0.36 ns | 1 | | | | |
| **TD** | 0.01 ns | -0.37 ns | 0.34 ns | 0.08 ns | -0.23 ns | 0.68** | 1 | | | |
| **MTY** | -0.31 ns | -0.59** | -0.1 ns | 0.13 ns | 0.02 ns | 0.65** | 0.67** | 1 | | |
| **UMTY** | -0.04 ns | 0.25 ns | -0.22 ns | -0.06 ns | 0.25 ns | -0.39 ns | -0.61** | -0.46* | 1 | |
| **TTY** | -0.35 ns | -0.58** | -0.16 ns | 0.13 ns | 0.08 ns | 0.61** | 0.59** | -0.26 ns | -0.26 ns | 1 |

**Abbreviations:** DTE=days to emergence, DTF= days to flowering, DTM=days to maturity, PH= plant height (cm), NTPP= number of tuber per plant (count), ATW= average tuber weight (kg), TD= tuber diameter (mm), MTY= marketable tuber yield (q $ha^{-1}$), UMTY= unmarketable tuber yield (q $ha^{-}$1), TTY= total tuber yield (q $ha^{-1}$).

**, and * denoted strong and moderate correlations between parameters while "ns" represented none significant correlation between parameters.

However, the strong (**r = -0.61**) negative correlation between unmarketable tuber yield and tuber diameter suggested that smaller tubers are more likely to be unmarketable. In line with this, it has been reported that smaller tubers in potatoes are often considered unmarketable due to their inability to meet size and quality standards in the market (Sharma et al., 2024). Moreover, the negative impact of tuber diameter on unmarketable yield may link to varietal difference and environmental factors that influence tuber formation. On the other hand, strong positive correlation (**r = 0.67**) between marketable tuber yield and tuber diameter indicated that larger tubers are more likely to meet market quality standards. This indicates that improving tuber diameter could significantly enhance the proportion of marketable tubers, thereby increasing overall yield quality.

In general, determining trait relationships is essential for selecting potato varieties with multiple desirable traits simultaneously.

# CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

## 5.1. Conclusion

- The study detected the significant impact of planting date and variety on growth and yield parameters, tuber number, total tuber yield, marketable tuber yield, unmarketable tuber yield and their associations.
- Early planting resulted in slower emergence, delayed flowering, and extended maturity, likely due to cooler temperatures and slower thermal accumulation
- The results demonstrated that the interaction effect of planting date and potato variety played crucial roles in selecting optimal planting schedules and suitable varieties to maximize potato productivity.
- Among the varieties tested, *Belete* consistently performed in terms of total tuber yield, average tuber weight, and marketable yield. This suggests that *Belete* variety is a promising variety capable of maintaining high productivity across different planting dates.
- Delayed planting time in late November, significantly reduced both marketable and total tuber yields whereas early planting on late October, provided the optimal growing conditions, enhancing tuber development by maximizing exposure to favourable moisture and temperature levels in *Raya Azebo* districts.
- The association among the studied traits indicated strong correlations between phenological traits, growth parameters, and yield components, indicating that early emergence, plant height, tuber size, and number of tubers significantly influence potato yield and quality.
- Generally, early planting and the use of high-yielding varieties like *Belete* are crucial for achieving optimal productivity and ensuring the sustainability of potato farming in regions with varying climatic conditions.

## 5.2. Recommendations

- It is critical to plant potatoes as early as possible to take advantage of the optimal climatic conditions available during the growing season.
- So, planting date around early November is recommended to ensure that potatoes have enough time for proper tuber bulking and to avoid the negative impacts of late planting.
- Additionally, *Belete* variety appeared as a high-performing variety in this study, making it an excellent choice for Raya Azebo districts where early planting is feasible.
- Farmers should consider the combination of early planting and suitable high-yielding varieties, such as *Belete*, to maximize both marketable yield and tuber quality.
- Moreover, efforts should be made to optimize planting schedules based on local climatic conditions, with a focus on avoiding late plantings that can reduce yields due to cooler temperatures and shorter growing seasons.
- Therefore, further research is also recommended to explore the underlying mechanisms by which planting date and variety interact to affect yield parameters, which could help adjust planting recommendations for different agro-ecologies.

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# Appendix tables

**Table 12. Mean squares for phonological and growth parameters of potato varieties under different planting dates**

| Sources of variation | DF | DTE | DTF | DTM | PHT |
|---|---|---|---|---|---|
| Rep | 2 | 0.778$^{ns}$ | 2.111ns | 30276 | 16.08 |
| Variety(V) | 2 | 3.444$^{ns}$ | 14.333$^{ns}$ | 29576.$^{ns}$ | 32.29$^{ns}$ |
| Planting date (PD) | 2 | 34.111** | 75.444** | 28876** | 34.49$^{ns}$ |
| V*PD | 4 | 1.556$^{*}$ | 3.444ns | 30269.$^{ns}$ | 41.39$^{ns}$ |

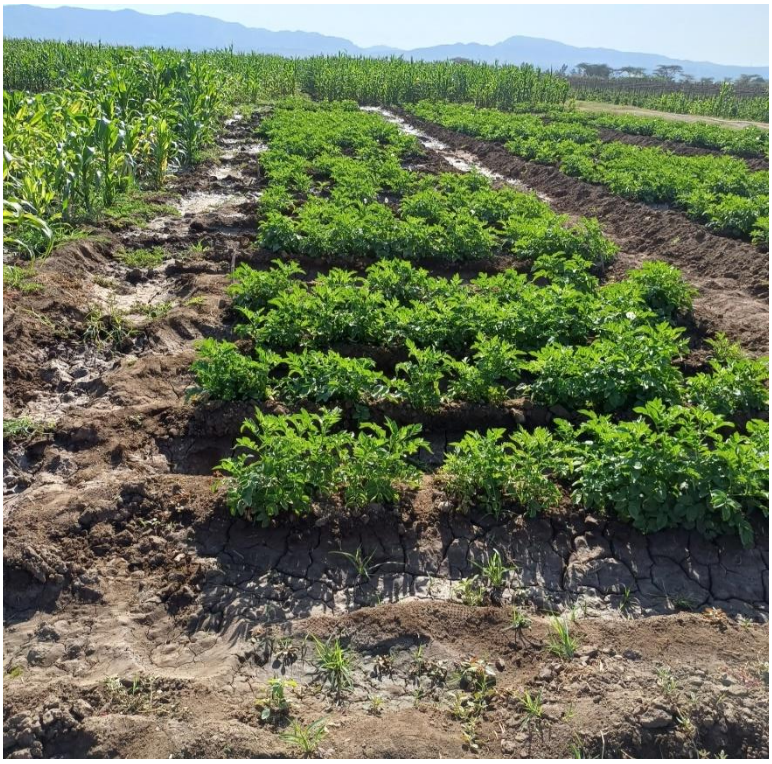
| | | | | | |
|---|---|---|---|---|---|
| Residual | 16 | 1.611 | 5.653 | 30120 | 36.89 |
| Total | 26 | | | | |
| CV | | 11.1 | 3.9 | 12.1 | 13.0 |

***Abbreviations:*** *DTE= days to emergency, DTF= days to flowering, DTM= days to maturity, PHT= plant height (cm),* LSD=least significances differences, NS= none significant difference, PD= planting date CV= coefficient of variance, ** means highly significant effect while NS denoted no significant difference.

**Table13**. **Mean squares for yield and yield related parameters of potato varieties under different planting dates**

| Sources of variation | DF | NTPP | ATW | TD | MTY | UNMY | TTY |
|---|---|---|---|---|---|---|---|
| Rep | 2 | 3.704 $^{ns}$ | 0.02938 $^{ns}$ | 3.752$^{ns}$ | 18.8$^{\mathbf{ns}}$ | 101.37$^{ns}$ | 224.5$^{ns}$ |
| Variety(V) | 2 | 17.593** | 0.08829* | 2.83$^{ns}$ | 8228.8** | 63.81$^{ns}$ | 9115.8** |
| Planting date (PD) | 2 | 17.593** | 0.11689** | 32.408$^{**}$ | 125274.7** | 685.11** | 7863.6** |
| V*PD | 4 | 2.315$^{*}$ | 0.01314$^{*}$ | 0.731$^{*}$ | 1738.8** | 10.81$^{ns}$ | 1749** |
| Residual | 16 | 2.620 | 0.01819 | 1.034 | 207.2 | 47.81 | 2957.2 |
| Total | 26 | | | | | | |
| CV | | 14.8 | 15.1 | 15.7 | 6.8 | 44.6 | 6 |

***Abbreviations:*** *Rep= replications, DF= degree of freedom, NTPP= number of tuber per plant, ATW = average tuber weight, TD= tuber diameter, UNMY =unmarketable tuber yield, LSD=least significances differences, NS= none significant difference, PD= planting date CV= coefficient of variance, ** means highly significant effect while NS denoted no significant difference.*



.

**Figure 1 Experimental plots during vegetative phases**

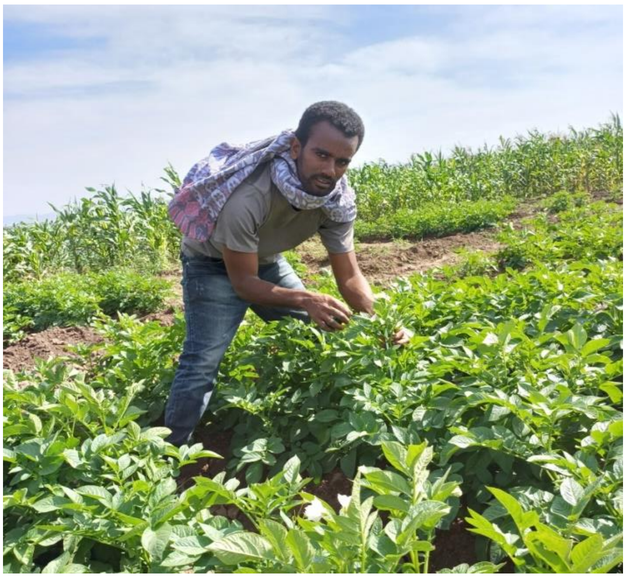


**Figure 2 the photo showing data collection**

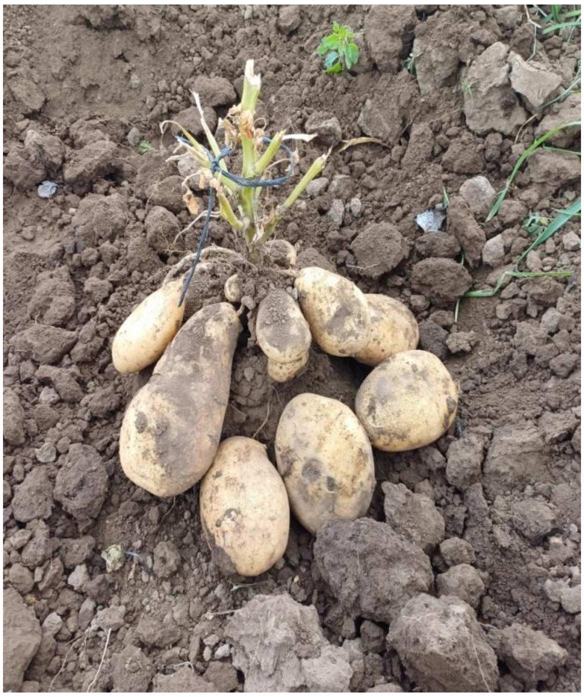


Figure 3 the photo showing tuber number

**Figure 4 the photo shows tuber yield**